National Bureau of Standards

TECHNICAL NEWS BULLETIN

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Damping Wind-Tunnel Turbulence

In wind-tunnel design, an important objective—next to acquiring high air speeds—is to obtain turbulence levels so low that motion through still air is actually simulated. Experimental research conducted at the National Bureau of Standards during the past few years has shown that damping screens are the most effective means for reducing turbulence in the test section of a tunnel. Doctors Hugh L. Dryden and G. B. Schubauer, aerodynamics experts who have directed the Bureau's work, report that fine screens across the section upstream of the entrance cone make it possible for the first time in the history of wind tunnels to get results that are truly representative of free flight. During the war years, uses for damping screens have increased with the realization that wind tunnels of low turbulence are a necessity in modern research.

A wind tunnel is a device used to produce an artificial wind in order to simulate the motion of a body through the air by moving the air instead of the body. The air stream or wind, enclosed by a circuit of ducts and moved by a propeller, is accelerated into the test section of smallest cross-sectional area through a nozzle or entrance cone. The contraction ratio (ratio of areas at the two ends of the entrance cone) is an important factor in wind-tunnel design, for the greater the contraction ratio the smoother and more uniform will be the wind in the test section.

Smoothness and uniformity of the wind are essential if the wind is to act on a body in the same way as it would if the body were moved through still air. The major difficulty with wind tunnels is that the wind is not perfectly smooth; it contains a fine pattern of eddies, known as turbulence, which originates in various parts of the circuit by virtue of the fact that the air must move over and around solid objects, such as the walls, guide vanes, and propeller.

Though wire screens have often been used to increase the turbulence of air streams, the same type of device may be used also to decrease turbulence. An analogy is the "smoothing" of a metal surface where a course file is first used to remove the larger roughness, reducing it to a roughness of a smaller scale. Then by using a finer file, sandpaper, and other tools with roughness of decreasing scales, a smooth surface is obtained. In a similar manner a screen "smooths" an airstream to the extent of decreasing turbulent motions of larger scale than the mesh size while at the same time introducing turbulent motions of smaller scale. Fortunately the small-scale turbulence decays much more rapidly than the large-scale turbulence, and hence at some distance from the screen the overall effect is a smoothing of the air flow in which both the intensity and the scale of the turbulence are reduced. Screens of fine mesh are therefore most suitable for use as damping screens.

The use of damping screens to reduce turbulence is of relatively recent origin. As far as is known the first observation of a damping effect on turbulence was made in 1934 in the old National Bureau of Standards $4\frac{1}{2}$-ft wind tunnel. Other indications of such an

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effect came from the observed steadiness of the flow in the Langley Field smoke tunnel of the National Advisory Committee for Aeronautics resulting from the use of a cloth over the tunnel entrance. However, the usefulness of damping screens was not realized until 1938 when measurements were made at the Bureau showing the turbulence reduction for a practical installation of a damping screen. A year later a systematic investigation of damping screens was undertaken at the National Bureau of Standards with the cooperation and financial assistance of the National Advisory Committee for Aeronautics. This investigation showed what could be accomplished with damping screens and how they could best be used to attain maximum results with a minimum consumption of power. A simple theory was also formulated which predicts results in good agreement with experiment.

Guest Research Program

Young scientists and engineers from foreign nations have for many years turned to the Bureau for advanced training and research in physics, chemistry, and engineering. Out of this demand has grown the so-called guest-worker program. The function of the program is to make available the facilities of the Bureau for post graduate study to a limited number of foreign scientists and engineers. Guest workers are entirely subsidized by the government or international organization that sends them here. The time spent at the Bureau ranges from a minimum of 2 weeks to a maximum of about a year.

In the beginning, each guest worker is assigned as an aide to a staff member doing fundamental research in the field of the student, who starts to do productive work by taking a responsible part in the projects under way. If the special interests of the guest worker are wider than the work done in a single section, he is assigned successively to two or three sections of the Bureau, so that the program is extremely flexible in terms of individual interests.

While the guest-worker program is just one of the arrangements enabling foreign scientists to investigate or participate in research at the Bureau, it plays a special role in helping to prepare younger scientists for creative research in their fields of scientific interest.

There have been 18 guest workers at the Bureau since May 1946, representing China, Czechoslovakia, Great Britain, India, France, and Spain. The special fields of study have included mining and metallurgy, electrical measurement, chemistry, weights and measures, building materials, electrochemistry, paints and varnishes, petrography, rubber, and optics.

The group of four guest workers now studying at the Bureau includes Mr. M. Lee and Mr. L. Wang from China, Mr. R. R. Rivlin from Great Britain, and Mrs. Doubravka Hajsman from Czechoslovakia. A fifth guest worker, Mr. L. Miranda, has just returned to Madrid.

Mrs. Hajsman, now working in the Petrography Section, was the first woman ever awarded an engineering degree from the Prague Technical University, from which she was graduated as a mechanical engineer in 1936. Prior to coming to the United States in 1939, she worked in the technical-literature section of the Skoda Works, Ltd., where she also tested and raced new models of the Skoda automobiles.

Mr. L. Wang, working in the Paints and Varnishes Section, is a chemist who worked with the National Bureau of Industrial Research at Chungking, China, during the war. Mr. M. Lee worked as a design engineer in a Chinese factory that was moved five times before it was completely bombed out by the Japanese. Following this, he was put in charge of development work on communications equipment for the Chinese government. Before coming to the Bureau to work in the Electrical Measurements Section he spent time studying electrical communications equipment at RCA, International Telephone and Telegraph, and other manufacturing companies in this country.

Mr. R. R. Rivlin, of the staff of the British Rubber Producers Association, is here verifying by experiment some theoretical conclusions derived from the mathematical theory of the mechanical properties of rubber on which he has been working. During the war he did research work in the fields of electronics, crystallography, and radar for the British Ministry of Aircraft Production.

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Contents

Radio Proximity Fuze

One of the most spectacular stories of highly secret weapons released since the war is that of the radio proximity fuze, officially known as the VT (variable time) fuze. This fuze automatically explodes a projectile at just the right time to cause the maximum damage to the target. It was one of the first weapons sought by the National Defense Research Committee, after its formation in August 1940, as a solution to the threat of enemy aviation. Under the joint sponsorship of this Committee and the Army, a project was initiated at the National Bureau of Standards for the development of a fuze for smooth-bore or nonrotating projectiles—such as bombs, rockets, and mortars. The development of this fuze ranks as one of the great scientific achievements of the war. Moreover, the developments and technics embodied in the fuze may be applied to such peacetime equipment as smaller hearing aids, pocket-size radios, walkie-talkies, and a variety of other miniature commercial electronic devices.

The radio proximity fuze is a tiny radio sending and receiving station, so small that some models may be covered by a man's hand. It operates by continuously sending out radio waves. When an object of reasonable size is approached, the radio waves reaching that object are reflected back to the projectile. The fuze receiver picks up these reflected waves, analyzes them, and when they have the desired properties (that is, when the projectile is close enough to the object), an electronic switch is closed, detonating the fuze and the projectile.

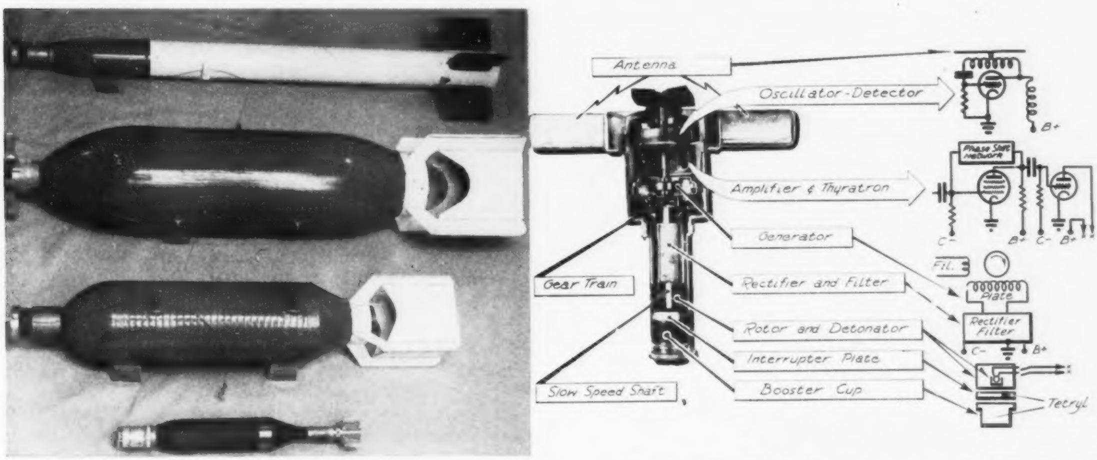
VT fuzes so far developed are all generally similar in that they have corresponding elements. These basic components are (1) miniature rugged vacuum tubes, which must be strong enough to withstand stresses as high as 20,000 g in gunfire; (2) a miniature rugged battery or generator to provide electric power; and (3) safety devices to prevent operation of the fuze until it has traveled a safe distance. The differences involve such factors as size, shape, detailed circuitry, and the type of safety means and electric-power supply.

Early Development

Work on fuzes for nonrotating projectiles got under way at the National Bureau of Standards in December 1940. From the beginning, speed was a primary consideration, and as each development was completed, an increasing number of projects was added. Beginning with a staff of eight in early 1941, the fuze development group grew into an organization of 400 in 1945, aided by the consultative service of all the regular Bureau Divisions.

Development work started much earlier in other countries. Great Britain was working on the idea in 1937 and sent a commission to this country in mid-1940, which gave American scientists the benefit of their experiences. Germany started work on similar devices in the early thirties but made the mistake of too great diversification of methods of approach.

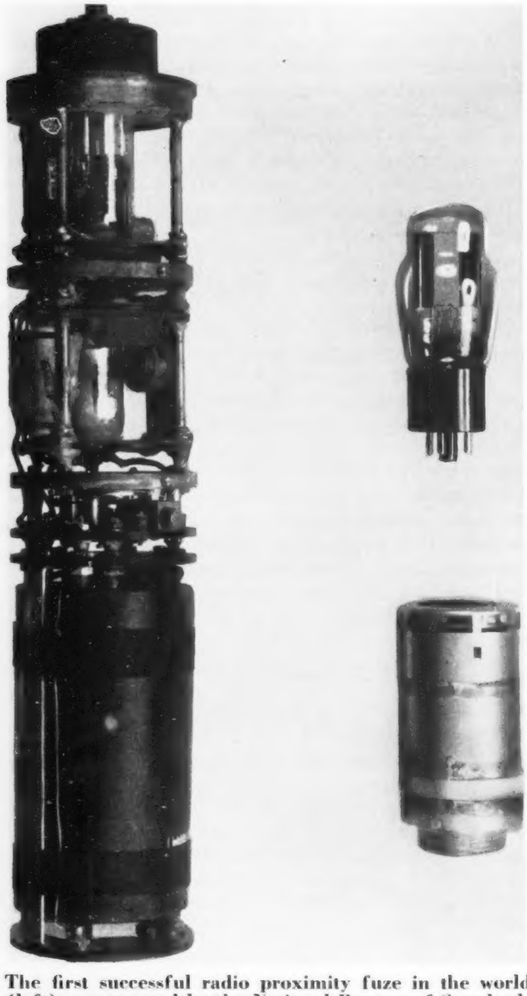
The first object of bomb-fuze development was to build a fuze to set off a rocket attached to a bomb after that bomb had fallen to within several hundred feet of a battleship. By this means, impact velocities high enough to penetrate and sink a battleship were expected. This requirement served as the first short-time objective, but it quickly gave way to a more general



Several missiles (left) with characteristic radio proximity fuzes developed by the National Bureau of Standards. At the bottom is an 80-millimeter mortar shell with generator-powered fuze, next a 260-pound fragmentation bomb with a ring-type fuze, then a 500-pound general-purpose bomb with a bar-type fuze, and at the top a 5-inch high-velocity aircraft-fired rocket with ring-type rocket fuze. Cutaway of bar-type fuze and circuit diagrams of primary subassemblies (right).

proximity fuze development program. In contrast to the Germans, our scientists spent a short time of careful preliminary experimentation on the various possible methods of obtaining such a fuze. Discarding all but two, they concentrated on the photoelectric and radio types. When the radio device proved superior all activity was devoted to it.

Fuze development was continually handicapped by testing difficulties. The electronic parts must produce radio signals that are constant to about 1 part in 10,000, despite the rough treatment the fuze receives in projectiles. A bomb approaches maximum velocity after it has fallen some 20,000 ft. This means that air turbulence and drag prevent the bomb velocity from increasing, and a large amount of energy is dissipated in sound and in vibration. The flight time of a bomb or rocket is never over 1 minute, which is a short time for experimental work on a remote, fast-moving object.



The first successful radio proximity fuze in the world (left), constructed by the National Bureau of Standards and tested by Bureau scientists at the Navy Dahlgren Proving Grounds on February 12, 1941, less than 2 months after initiation of the program. The dimensions of this fuze, excluding the whip antenna and battery (not shown), were 14 in. in length and 3¼ in. in diameter. In contrast, the later generator-powered proximity fuze (right) for mortars measures only 4¾ in. in length with an over-all diameter of 2 in. Note conventional radio tube for size comparison.

The M-8 Rocket Fuze

In May 1942 the National Bureau of Standards was requested to develop a VT fuze for a new Army 4.5-in. airborne rocket, the M–8. After consultation with Army ordnance engineers and the NDRC, Bureau scientists completed designs within 2 days, and construction of test fuze lots began. The final design consisted of three primary parts: the fuze head, containing the electric circuits; a new and quite small dry battery; and a switch, interrupter, and booster mechanism.

Development and testing of the radio proximity fuze were hindered by variable winds and swaying targets, but these difficulties were relieved by two simultaneous developments. Highly selective fuze circuits were devised using feedback principles, and a method of using a fixed ground target was found At this point it is relevant to point out that VT fuzes are not activated by objects moving parallel to the fuze projectile and at the same velocity. From this it is obvious that if the VT-fuzed projectile is made to travel parallel to a level plane, it will not operate on that level surface; it must approach that surface to function.

More than 1,000 fuzes were built in the Bureau's model shops during June and July, and by August 1942, the first detailed specifications were completed. Production was started in the latter part of 1942 and continued through most of 1943. About 400,000 each of the radio and photoelectric proximity fuzes were manufactured.

Although this radio proximity fuze was developed primarily for use against aircraft, the design quite fortunately proved correct either for use from airplanes against troops and gun emplacements, or for use from the ground against such targets. One spectacular application was its use as a barrage weapon from large tanks.

At the same time the Ordnance Development Division of the National Bureau of Standards, under the leadership of Harry Diamond, was organized and began functioning as a separate Division of the Bureau, devoting its entire time and energy to the development of proximity fuzes.

The Bomb Fuze

Upon the successful completion of the rocket-fuze developments, a similar fuze for possible use in air-to-air attacks on enemy bomber formations was requested by the Army. As the war progressed, however, and the tactical situation changed, it became evident that targets for such weapons were becoming scarce, and that fuzes for air-to-ground use to provide an air burst

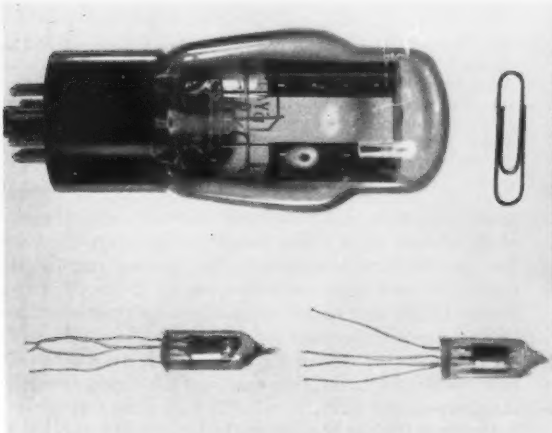
Target range at the National Bureau of Standards proving ground at Fort Fisher, N. C., shows the launching tower at left and the mock-up target of wire netting at right. Ground between tower and target has been leveled to avoid undesired reflections from ground. Note proximity burst near the tip of the left wing of the target "plane."

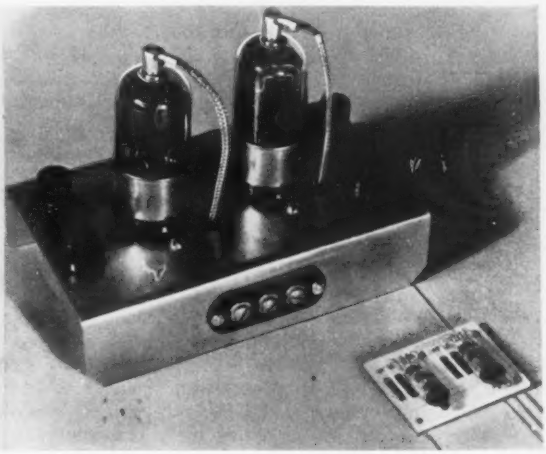
over personnel and light-material targets were more desirable. The major share of attention for the ensuing year was devoted to this problem in its varied aspects.

Certain design considerations were evident in the initial survey of the bomb-fuze problem. Because the vehicle on which the fuze is mounted and the application are different, the electronic circuit had to be changed from that of the rocket fuze. The space into which the fuze must fit necessitated physical redesign; and as a bomb is not subject to set-back at release, as is a rocket fuze, a new arming mechanism was necessary.

Experience in the development of the first rocket fuze demonstrated that the usual type of dry battery is not very satisfactory as a power source. It deteriorates rapidly in storage and will not work at the subzero temperatures encountered by high-flying bombers. To be fully useful in the military sense, a weapon must be rugged enough to withstand any possible kind of handling or storage. It became a matter of first importance to devise a means for supplying power to the fuze which met all requirements of military usage.

In the initial development of VT bomb fuzes, the "longitudinal excitation" type of antenna was utilized, because both the air-to-ground and air-to-air aspects had to be kept in mind and because electric circuits





Compact size of proximity fuzes results from the development of miniature components. Two subminiature tubes are contrasted with a conventional radio tube and paper clip (left). Such tubes were developed by the Bureau in cooperation with industry and other laboratories. Right: Conventional two-stage amplifier and a radio fuze printed ceramic control circuit developed by the Bureau for use with subminiature tubes. These new developments have wide peacetime applications.

for this type of fuze were better known. Soon after, work on the "transverse excitation" type of antenna was also initiated. The "transverse excitation" type of fuze offered certain advantages in air-to-ground bombing. Specifically these advantages were (1) good performance from high altitude, (2) less dependence on bomb dimensions, (3) greater sensitivity, i. e., greater burst heights.

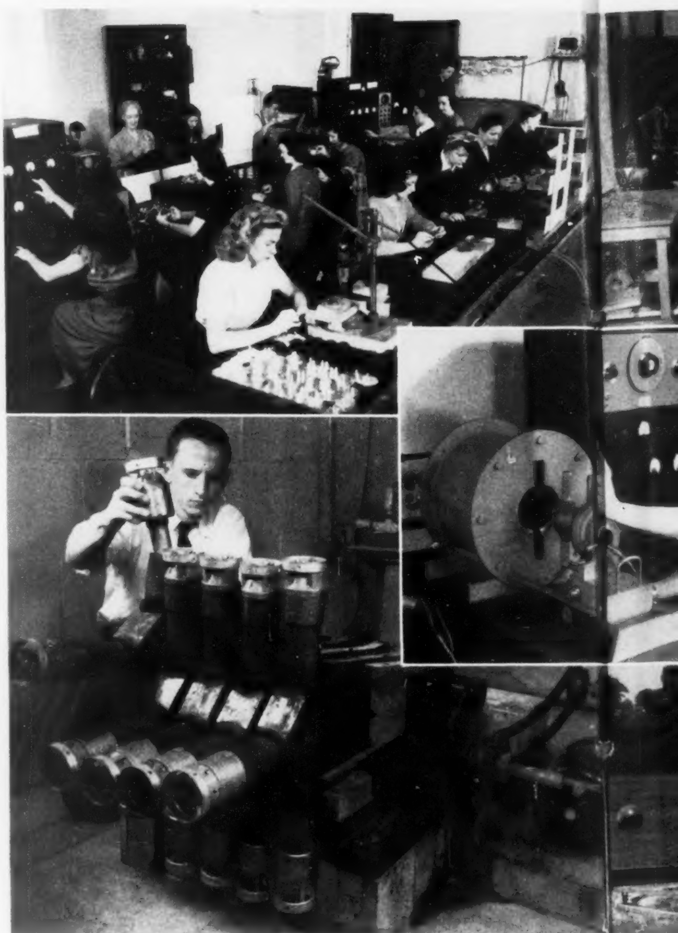
An air-travel arming system was selected. In this system a small vane at the front of the fuze actuates the arming mechanism so that arming occurs only after this vane has turned through a certain number of turns, representing a definite amount of travel through the air after release of the bomb.

Use of a wind-driven propeller for arming leads naturally to a solution to the power-supply problem. As there is already a rotating system present, this may be utilized to drive a generator which supplies the necessary electric power for the fuze. The requirement for a generator of small size, high power output, rugged design, stable operation, and simple construction led to the development of a permanent-magnet alternator. The rotor consisted of a very strong but small disk magnet made of Alnico. Coils were mounted on a magnetic stator surrounding the rotor. An electric regulator circuit was developed for this generator which maintained constant generator power output even though the rotational speed of the generator varied over a range of three to one.

Early in the bomb-fuze program, when it became apparent that major difficulties would be experienced with the propeller type of driving mechanism, means of altering the mechanical system in such a way as to minimize the vibration resulting from the rotation of the propeller and the generator rotor were considered. By using a turbine, mounted inside the fuze immediately adjacent to the generator rotor and driven through an air-intake duct in the center of the fuze, it is possible to make the rotating system more compact. By locating the generator within the fuze well of the bomb, the entire rotating system is mounted close to the point of support. Such an arrangement reduces the amplitude of vibration and accomplishes a substantial reduction in over-all length.

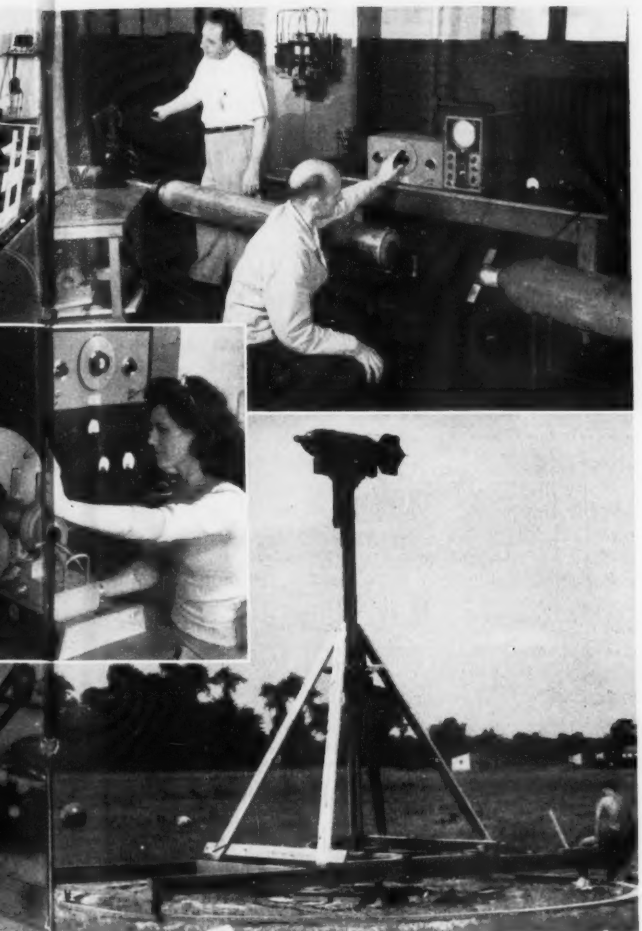
The development of the generator was a milestone in proximity-fuze design, but it was not an unmixed blessing. Normal commercial machinery runs at speeds not greater than 3,600 rpm. High-speed tools run at about 12,000 rpm. In these small VT-fuze generators, design considerations required speeds in excess of 50,000 rpm. At such speeds, mechanical stresses and the resulting vibration are great. Much effort was devoted to bearing design, to balancing the rotating mechanism, and to improving the rotor structure so that it would not fly apart at such high speeds. All of these problems were solved satisfactorily, and the wind-driven generator was accepted as the standard power supply for VT bomb fuzes.

In the early stages of manufacture, as in the early stages of preliminary production, extreme difficulty was encountered in making the generator-type fuze, due primarily to the vibration associated with the rotating system and to a lesser extent to the vibration of the bomb itself. The vibration problem remained the most difficult single problem throughout the development and early manufacture of the bomb fuzes. It was found necessary to manufacture certain critical mechanical components to extremely close tolerances and to develop miniature radio tubes which were insensitive to vibration to a degree previously unknown.



The "pilot" line of the radio proximity fuze model shop of the Bureau models and improvement (top left). Using an airstream from a calib properties of a bar-type fuze mounted on a 100-pound general purpose fuze, the fuze is placed in a chamber where the propeller is driven by quality data (center). Jolt testing machine (lower left) ensures safet field. Part of the apparatus (lower right) used to measure the sensitivi made every 5 degrees of rotation for 1 revolution of the platform carry

Preliminary service tests of the bomb fuzes led to minor modifications in the course of production. Chief among these was a device to provide delay in arming (in addition to that built into the fuze) which could be adjusted in the field to permit the fuzes to be dropped safely through deep formations of bombers.



of the Bureau played an important part in the development of fuze from a calibrated jet, Bureau scientists determine the aerodynamic eneral purpose bomb (top right). In the final test of the bar-type r is given by an air jet, simulating operation and providing over-all ensures safety of fuzes by simulating rough handling of the battle- re the sensitivity of radio fuzes at different angles. Measurements are platform carrying the bomb.

It consisted of a small auxiliary vane and gear train externally clipped to the fuze, which released the fuze vane after a preselected amount of air travel.

The Army Ordnance Department then requested that the fuze be designed to operate on all standard bombs from 100-pound to 1,000-pound sizes. An extensive investigation showed that the various bombs exhibited marked variations in their radiation properties. It was found that by making two fuzes, one for the smaller bombs and another for the larger bombs, the range of bomb sizes could be satisfactorily covered and good performance achieved on each bomb. The fuze initially developed served, with a slight modification, for one group of bombs, and a second fuze was designed for the other group of bombs.

The Generator-Powered Rocket Fuze

After the bomb-fuze development had passed into the manufacturing stage, the Navy proposed that this type be adopted for use on the new Navy "5" aircraft rockets. These rockets can be fired from airplanes with remarkable accuracy, using launching equipment so small that it adds very little drag to the airplane. Eight of these rockets are mounted under the wings of airplanes, thereby providing them with the equivalent of heavy-caliber guns.

Development of a new rocket fuze meeting all service requirements was virtually complete in June 1945. It featured an enclosed turbine drive for the generator and gear train, self-destruction and variable arming time as field options, and a change-over switch for air-to-air or air-to-ground operation. The mechanical design was similar to that for the mortar fuzes, there being considerable reduction in size over previous rocket fuzes.

After VT fuzes had been successfully developed and produced for all common projectiles except trench mortars and designs had progressed to the point where a VT fuze small enough for the 8-pound mortar projectile appeared possible, NDRC and the National Bureau of Standards were asked to undertake this development.

The design of a fuze for the 8-pound mortar required the solution of two major problems: ruggedness and size. Whereas the early rocket fuzes were designed to withstand a shock 1,000 times the force of gravity, and the bomb fuzes had to stand up under normal rough handling in use, a mortar fuze must withstand a firing shock 10,000 times the force of gravity. In addition, mortar projectiles are so small that fuzes of the size of those used on bombs would spoil the flight of the projectile and make the round useless.

Early design work followed two general patterns. A novel and highly significant feature of one design was the manufacture of circuit components, such as resistors and condensers and the connections between them, by a new process involving the use of ceramics, thereby obtaining a material saving in space. This is a radical departure in assembly technic and may relegate other methods to the museum. The second design used a small loop antenna instead of the projectile body antenna. The circuit design and power supply followed closely the designs of previous fuzes. The operating characteristics of the two types of fuzes differed in the same manner as the characteristics of the two types of bomb fuzes previously described.

Again the urgency of the need for the fuzes dictated production prior to completion of development. Development and preparations for production proceeded simultaneously and in June 1945 production got under way.

Production

From the production viewpoint the radio fuze presented an enormous challenge to production engineers. It is generally called an electronic device, and yet it is more complex mechanically than electrically. Once the electrical arrangements had been established, the

primary task was one of mechanical assembly of considerable intricacy. Designs required a nice balance between the perfection and the producibility of each part. The radio fuze is comparable to a highly sensitive radio instrument electrically and to a fine time fuze mechanically. Few manufacturers were completely qualified in both fields. Manufacturers of electronic equipment had to learn new skills in the precision mechanical field. Firms skilled mechanically had to learn electronic technics and procedures. Add to this the fact that in each instance production was required before the development work was complete, and it is apparent that the production task was as large and difficult as the development of the fuze. To handle its phase of the task, the Bureau established a Production Engineering Section in March 1943.

As each fuze design progressed to the point where minimum satisfactory performance was achieved, production was started immediately. Meanwhile, development was proceeding with the primary objective of improving the fuze performance.

After about 2 years of intense effort, backed by industrial experience in vacuum-tube production, fuzes were in production and available to our armed forces throughout the world. To prevent the enemy from capturing and duplicating the fuze, its use was limited to naval activity on the high seas until the last stages of the war when it was too late for the enemy to use the information.

With the end of the war and the declassification of the principle of the VT fuze, industry is manifesting interest in the program of miniaturization of electronic devices. Many industrial and Government organizations are conferring with the National Bureau of Standards concerning ways in which such developments as printed electronic circuits technics, wind-driven generators, and subminiature electron tubes might be adapted to their own work. Examples of the equipment to which proximity-fuze technics might be directly applied include the manufacture of I-F strips for radar equipment, control circuits in pilotless aircraft, portable radio transmitters and receivers concealed on the persons of intelligence personnel, subminiature electronic controls, a greatly expedited telephone dialing system, special research equipment, and a host of other commercial applications.

War Department Awards

Awards in recognition of war work were made to three Bureau scientists recently by the War Department. Lauriston S. Taylor, Chief of the X-Ray Section, received the Medal of Freedom, America's second highest award for civilian wartime achievement, and the Bronze Star Medal. Fred L. Mohler, Chief of the Atomic Physics Section, was awarded the Medal of Freedom, and Harold O. Wyckoff, physicist in the X-Ray Section, received the Bronze Star Medal. All three served with operational research and analysis units of the Ninth Air Force in Europe.

Research Fellowship on Reinforced Concrete

The prime objectives of the research program on reinforced concrete now under way at the Bureau by a fellowship of the American Iron and Steel Institute are improved design of concrete reinforcing bars and engineering data that will enable engineers and builders to make more effective use of reinforced concrete.

Reinforced concrete is essentially concrete into which reinforcing materials, usually steel bars, have been incorporated to give added strength. A mechanical bond—that is, a bond that will resist slipping of the bar within the concrete—is set up between the reinforcement and concrete, and the effectiveness of the reinforcement is dependent on this bond. The investigations by the fellowship constitute fundamental research into the mechanism of this bond, and the factors that affect the bond strength between the concrete and the reinforcing bars.

Reinforcing bars, with ribs or ridges of various patterns, are known as deformed bars, and as many as 20 designs of these bars are commercially available. Although it is generally recognized in the industry that some of these are more effective in developing bond than others, minimum requirements for deformed bars have not been established. One purpose of this investigation is to set up criteria that will define a satisfactory deformed concrete reinforcing bar and eliminate the less effective of these designs. On the basis of preliminary data, the members of the American Iron and Steel Institute who are producers of reinforcing bars have discarded from further consideration all but five designs.

The test procedure for determining relative bond efficiency, prepared through the cooperation of a committee of the American Concrete Institute, of which H. J. Gilkey is chairman, has been published as a proposed standard of the American Concrete Institute. Taking into account the many factors that affect the character of the bond, specifications cover the composition and quality of the concrete, the location and length of embedment of the bars in the concrete, construction of the molds and assemblies, details of casting and curing, and methods of testing the finished specimen. Test specimens are beams 6½ ft. long, 1½ ft. high, and 8 in. wide. For this series of tests nominal ⅞-in. bars, the most commonly used size, have been specified. It is anticipated that other sizes will be tested later.

The fellowship at the National Bureau of Standards, one of several supported by the American Iron and Steel Institute at various institutions, operates under the Bureau's research fellowship plan. According to this plan, groups or organizations whose research programs fall in fields within the Bureau's scope of activities may be permitted, under certain conditions, to establish research fellowships for investigation of problems of mutual interest in these fields. Such fellowships are granted the complete facilities of the Bureau's laboratories and results of their work are made available in the same manner as those of other

Bureau laboratories. Known as research associates, their personnel are accorded all privileges of Bureau employees.

Established in 1944, the American Iron and Steel Institute fellowship consists of five employees, under the immediate supervision of Arthur P. Clark, research associate, formerly of the Bethlehem Steel Co. Along with other research projects on reinforced concrete conducted by the Institute, the work of the fellowship is planned and directed by the Institute's Committee on Reinforced Concrete Research. Roy R. Zipprodt is research engineer for the committee.

Laboratory facilities and equipment have been provided by the Bureau's Masonry Construction Section, with which the work of the fellowship is closely associated. The fellowship is now undertaking more exhaustive bond tests with seven varieties of bars, including the five indicated by the preliminary tests to be most desirable from all standpoints. Data from these tests will provide the industry with information that will permit them to develop better deformed bars. The results of the preliminary tests, however, have indicated desirable modifications in design, some of which have already been put into effect.

Steel Plates for Welded Ships

The strength of large welded steel structures, brought into prominence during the war by Liberty ship failures, is being investigated by the Structural Steel Committee of the Welding Research Council in cooperation with the Engineering Mechanics Laboratory of the Bureau. Tests already concluded indicate that factors of design, as well as welding, have an effect on the initial formation of a crack. The continuation of a crack depends upon the notch sensitivity of the steel, a property overlooked in past specifications for ship plate.

Six 9-ton welded structural carbon steel box-girders of 22-ft. span, with an over-all width of 2 ft. 6 in. and depth of 2 ft. 1.5 in., have been constructed at the Ingalls shipyard, Pascagoula, Miss. Very abusive welding procedures and sequences were used, along with some unfavorable details of design, for the deliberate purpose of producing the highest possible residual stresses, especially in the vicinity of the transverse closing butt of the tension flange, which was welded last under extreme conditions of restraint. The tension flange plate is fitted between the side web plates to simulate the joints between the deck of a ship and the side plating when the ship is subjected to "hogging" stresses (with an elastic curvature that is convex upward).

The girders have been successfully proportioned to insure against failure by lateral deflection and buckling or twisting, the manner in which test beams and girders usually fail. The compression flange was made 2½ in. thick.

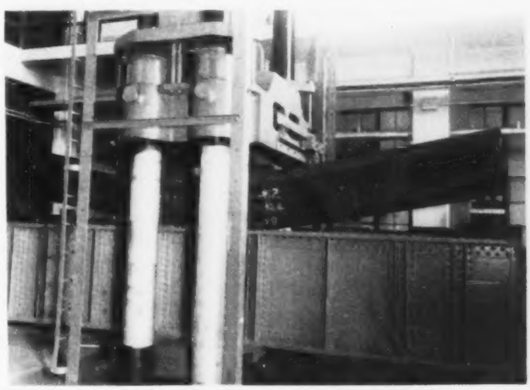
The first girder, constructed of ordinary semikilled structural steel hull plating taken from stock in the shipyard, was tested at room temperature. It failed by rupture with a brittle or "cleavage" type of fracture and a sudden release of energy that shook the building. Failure did not occur until the measured strains and elastic deflection indicated extreme fiber stresses approximately equal to the conventionally determined ultimate tensile strength of the material, not far below the modulus of rupture of 75,600 lb/in.^{2} as computed for the breaking load of 1,397,000 lb and corresponding bending moment of 71,200,000 lb.-in. Total deflection at failure was about 8 in., about 7 in. being permanent set and less than 1-in. elastic deflection.

The second girder, of fully killed steel, tested at about −45° F failed in a similar fashion, but the fracture was more of a compound, shattering type under the influence of cold temperature, and the entire girder snapped in two. The breaking load of 1,165,000 lb was only 16.5 percent lower than that for the first girder, although it was 30.9 percent lower than the maximum load imposed upon the third girder, which was tested at room temperature.

The third girder, of fully killed steel, did not fail under a load of 1,685,000 lb equally distributed between two load points 2½ ft on either side of the midspan, when the center deflection reached 18.06 in. At this point, the girder was almost touching the supporting girders of the test apparatus, and further loading was impossible. The permanent center deflection after removal of the load was 16.45 in. The extreme fibre stresses, computed under this loading, were 91,200 lb/in.^{2} in the projections of the side plates and 70,200 lb/in.^{2} in the tension flange plate. It is probable that 70,200 lb/in.^{2} stress was actually realized. Data like the extensive strain gage readings still remain to be analyzed.

The purpose of the research program is to investigate, at various significant temperatures, (1) the effect of severe geometrical constraint against ductile behavior and upon the capacity of a welded structural member for resisting rupture under external load, and (2) to observe the detrimental effects of residual stresses.

The character of future tests has not been decided. The testing of girders preheated during welding, testing at various intermediate temperatures, and studies of the effects of normalizing heat treatments subsequent to



This 9-ton, 22-foot girder of fully killed structural steel, third to be tested in a series of studies on large welded steel structures, is shown sustaining a load of 1,685,000 pounds. Center deflection reached 18.06 inches.

construction of the girders, are all contemplated. Out of these tests, a fuller knowledge of the behavior of large welded steel structures and data that may lead to the design and construction of more satisfactory members are expected.

Revised Building Code

Safety factors, which must be kept in mind in the drive to increase the supply and reduce the cost of housing, are stressed in a new publication on building code requirements issued by the National Bureau of Standards, acting in a consultant capacity for the National Housing Agency.

The proposed code aims at providing sound construction without excessive cost and with adequate provision for recognizing new developments in construction technics and materials as they occur. The proposals cover such matters as design loads for floors, wind pressures on roofs and walls, snow loads, working stresses for building materials, fire protection, design of chimneys and fireplaces, precautions concerning installations of heating appliances, and simple measures to prevent injuries due to improper construction. Such a code, dealing with safety matters only, will not assure a buyer or occupant of a house that the structure will be satisfactory in all respects, but it is felt that there are many features of a house which, if meeting adequate safety requirements, will also give good performance otherwise.

The principle followed in the code is to require accepted good practice and then to recognize conformity to well-developed standards as evidence of such practice. Standards developed by representative national committees of industrial, professional, and governmental groups are used as the base, with modifications and changes as suggested by experiment and experience. Ample provision is made for new and unusual construction, not covered by existing standards, by acceptance through test. Although reference to minimum standards is a growing practice in building code revision, it is realized that the use of the new code in place of minute and detailed requirements may be unfamiliar to some designers and builders and may be illegal in some jurisdictions. To cover such situations, an appendix has been added which presents the specific provisions consistent with the requirements of the standards.

The new publication, which is a revision of an earlier one prepared some years ago by a committee of the Central Housing Committee entitled "Recommended Building Code Requirements for New Dwelling Construction," is generally limited to the field of individual dwellings and small apartment houses, which are the crux of the present housing problem. It will be valuable as a guide when state and local preparation or revision of building codes is undertaken.

Identified as Building Materials and Strucures Report BMS107, copies of this publication are now available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C., at 20 cents each.

High Wet-Strength Paper

A new paper, possessing unusual qualities that made war maps durable in the water, mud, and grime of the battlefield, was developed early in the war by the Army Engineers in cooperation with the National Bureau of Standards. High wet-strength, obtained by the relatively new development of resin bonding, constitutes the most important feature of this paper, which is resistant to conditions that disintegrate conventional papers. Following the developmental and semicommercial paper-making experiments, the Bureau played an important role in carrying the new type of paper into commercial production. Though developed primarily for war maps, this high-strength paper offers numerous yet unexplored peacetime uses—such as bed sheets, bath mats, washable towels, wrappings for wet meats and vegetables, and outdoor advertising.

The specifications for this paper were very stringent. They called for the rugged strength—dry, wet, or oil soaked—that gives maps their durability. In addition, they called for low expansivity; high opacity whether wet, dry, or oily; good writing quality, wet or dry; low acidity; and smoothness suitable for printing multicolor line maps and 200-line photomaps. Close limitations were placed on thickness, weight, and moisture content. Experiments at the Bureau determined how such paper could be made from available raw materials.

The extremely high strength required for the map paper made it essential that all or a large proportion of the fibers used be of high strength. Rag fibers were not considered because neither an adequate supply of rags nor sufficient rag-cooking equipment was available to meet anticipated needs. Hence, the experiments were confined to commercially available bleached wood pulps: three types of bleached sulfate, bleached sulfite, deciduous wood soda, and deciduous wood sulfite.

Experimental papers from these pulps were made in the Bureau's pilot paper mill, which is semicommercial in size, and adapted to the experimental manufacture of papers under conditions that simulate those of industrial plants. The manufacturing process for the high wet-strength paper follows the same steps used in making conventional paper, the only differences being a shorter beating cycle and the addition of resin bonding. The key to the high-strength paper is the melamine-formaldehyde resin, which is added continuously to the stock leaving the screen just before it enters the head box of the paper machine. The resin is added as a colloidal solution—made by dissolving resin in the form of a fine white powder—in warm water acidified with hydrochloric acid. The solution is uniformly mixed with the stock by baffles in the head box, where the temperature is maintained at $90°F \pm 2°$.

The best results were obtained in experimental manufacture by using fiber furnishes of 100-percent strong bleached sulfate pulps with melamine-formaldehyde resin for wet strength and titanium dioxide for opacity. It is essential that the beating be very carefully controlled to preserve the maximum fiber strength. The

most critical requirements from a manufacturing standpoint are very high resistance to tear, high wet-tensile strength, high opacity, and good smoothness. A moderate degree of wildness is not objectionable.

When it became important to explore the possibilities of saving space and weight in the shipment of maps by air, a lightweight paper was developed that reduced the shipping weight and bulk of maps by 25 percent. It was composed of 100 percent of the strongest bleached fibers with 3 percent of melamine resin and 3 percent of titanium dioxide. This paper, made with absolute minimum of beatings, was produced in quantities sufficient for printing trial lots of maps that were used by the Army Engineers to establish the utility and durability of lightweight maps.

With the information gained in the experimental work, it was possible to give maximum assistance in extending the commercial manufacture of the paper to widely distributed mills so that the unprecedented needs of the armed forces could be met quickly. Technical service was provided for mills on their initial orders, and more than a dozen mills were soon able to make paper meeting the Army's high standards. All of these mills initiated the manufacture by following specific technical instruction from the Bureau. The success in applying the information is shown by the consistent manner in which the various papers conformed to, and in many instances exceeded, the most difficult requirements of the specification. Production exceeding 10,000,000 lb per month, within approximately 6 months after initiation of commercial manufacture, was accomplished with a minimum of delay or loss of critical raw materials.

That these papers were well made is attested by the following statement in a letter of commendation from the Office of Chief of Engineers: "Millions of maps have been printed on this high wet-strength paper and their superior durable qualities have proved eminently satisfactory to troops in all theaters of war." Experiments are continuing at the Bureau to develop even more durable and stronger papers.

Revision of Elevator Safety Code

The American Standard Safety Code for elevators, dumbwaiters, and escalators, sponsored jointly by the American Institute of Architects, the National Bureau of Standards, and the American Society of Mechanical Engineers, is now being revised. As a result of the better code requirements in the American Standard Elevator Code and the testing and certifying of these safety devices, the number of elevator accidents throughout the United States has shown a steady decrease during the past 20 years, although the number of elevators in use has increased materially.

The usual periodic revision scheduled for 1943 was held in abeyance because of the pressure of war work. The 1947 edition is expected to be clearer in intent and fuller in coverage than previous editions, and will be arranged to require the minimum number of cross references. At present 10 subcommittees are at work on particular phases of this revision.

For 25 years the National Bureau of Standards has taken an active part in the preparation of this important standard. In 1922 the Bureau was asked to set up equipment for testing elevator hoistway door interlocks. To provide the necessary data, a survey of several thousand elevator landings equipped with interlocks was made by Bureau engineers. Test procedure to detect some of the commoner weaknesses and causes of failure found during this survey were prepared by the Bureau, and these test specifications were approved by the Sectional Committee with minor modifications. They have remained substantially unchanged since that time. Equipment which meets these tests may be expected to have reasonably long life even under adverse conditions such as moisture and lack of lubrication. Of greater importance from the safety standpoint, any mechanical or electrical failure of such device will not cause unsafe operating conditions.

Subsequently, after several years of research work at the Bureau, test specifications were set up for undercar hydraulic buffers, approved by the Sectional Committee, and included in the 1931 edition of the code. Type tests on such equipment are made by the National Bureau of Standards. Where an interlock or buffer meets code specifications, a certificate of compliance is issued. Such certified interlocks and buffers are required by a number of states and cities as well as by various branches of the Federal Government.

Ramberg Succeeds Whittemore

Herbert L. Whittemore, mechanical engineer, authority on the testing of engineering materials, and chief of the Engineering Mechanics Section since 1918, retired on October 31 after 29 years of continuous Government service. Mr. Whittemore has directed extensive mechanical tests of engineering materials, including cooperative investigations of the strength of welded joints, pressure vessels, steel cables, thread locking devices, stainless sheet, rigid frames, steel columns, and welded steel girders. He developed the Whittemore Strain Gage and the Whittemore-Petrenko Proving Ring. This proving ring has become standard equipment in the calibration of tension and compression testing machines, and won him the Longstreth Medal of the Franklin Institute in 1938. For his basic research in oxyacetylene welds and his success in promoting the use of safe fusion welding, he was awarded the James Turner Morehead Medal of the International Acetylene Association in 1928.

Walter Ramberg, a member of the Engineering Mechanics Section for 15 years and in charge of the aircraft structures group since 1937, has been designated to succeed Mr. Whittemore. Dr. Ramberg is well known for his work in aeronautical research. He has contributed extensively to scientific literature on the strength of materials, the strength and instability of structural elements of aircraft, and the vibration of propellers. The most recent of a number of measuring instruments developed by Dr. Ramberg is an electronic

tube known as a vacuum-tube acceleration pickup, designed to record rapidly changing accelerations of portions of an airplane in flight. For his "outstanding achievement in the engineering sciences," he received the 1942 award of the Washington Academy of Sciences. Dr. Ramberg is a member of the Subcommittees on Aircraft Construction and on Vibration and Flutter of the National Advisory Committee for Aeronautics.

Snoke Appointed Section Chief

Hubert R. Snoke has been appointed chief of the Bituminous, Detergent, and Miscellaneous Materials Section of the Chemistry Division, to succeed F. W. Smither, who retired on August 31. Effective with the appointment is the transfer of the bituminous materials laboratory from the former Paint, Varnish, and Bituminous Materials Section to Mr. Snoke's supervision.

Mr. Snoke is a national authority on bituminous and other roofing materials. His "Building Materials and Structures" reports cover a comprehensive survey of roofing materials and construction in all sections of the United States. During the war, he served as a consultant to the War Department in this specialized field. Mr. Snoke is chairman of the Technical Committee on Bituminous Roofing of the Federal Specifications Board and is a member of the Committee on Bituminous Waterproofing and Roofing Materials of the ASTM.

New and Revised Publications Issued During December 1946

Journal of Research [1]

Journal of Research of the National Bureau of Standards, volume 37, number 6, December 1946 (RP1752 to RP1757, inclusive). 30 cents. Annual subscription, 12 issues, $3.50.

Research Papers [1]

RP1732. Heats, equilibrium constants, and free energies of formation of the alkylbenzenes. 15 cents.
RP1737. Theory for axial rigidity of structural members having ovaloid or square perforations. 10 cents.
RP1738. Heat content, free-energy function, entropy, and heat capacity of ethylene, propylene, and the four butenes to 1,500° K. 10 cents.
RP1739. A simple cyclic falling-film molecular still. 5 cents.
RP1740. A study of resinous sealants for porous metal castings. 10 cents.
RP1741. Testing large-capacity rotary gas meters. 15 cents.
RP1742. Poisson's ratio of some structural alloys for large strains. 10 cents.
RP1743. Electrode function (pH response) of potash-silica glasses. 10 cents.
RP1744. Purification and sealing "in vacuum" of National Bureau of Standards Standard Samples of hydrocarbons. 10 cents.
RP1745. Thermal-expansion stresses in reinforced plastics. 10 cents.
RP1746. Salt effects of potassium nitrate, sodium sulfate, and trisodium citrate on the activity coefficients of p-phenolsulfonate buffers. 10 cents.

Basic Radio Propagation Predictions [1]

CRPL–D28. Basic radio propagation predictions for March 1947 three months in advance. Issued December, 1946. 15 cents. Annual subscription, 12 issues, $1.50.

Circular [1]

C453. Apparatus for determining water-vapor permeability of moisture barriers. Frederick T. Carson and Vernon Worthington. 10 cents.

Simplified Practice Recommendations [1]

R70–46. Salt packages. (Supersedes R70–42). 5 cents.
R174–47. Cast-iron radiators. (Supersedes R174–43). 5 cents.

Technical News Bulletin [1]

Technical News Bulletin 356, December 1946. 5 cents.

Mimeographed Material

Letter Circulars

(Letter Circulars are prepared to answer specific inquiries addressed to the National Bureau of Standards, and are sent only on request to persons having a definite need for the information. The Bureau cannot undertake to supply lists or complete sets of Letter Circulars or send copies automatically as issued.)

LC838. Concrete and reinforced concrete—publications by members of the staff of the National Bureau of Standards with a list of Federal Specifications. (Supersedes LC642.)
LC839. Dental materials—publications by the staff of the National Bureau of Standards and research associates on dental materials. (Supersedes LC558.)
LC840. Home heating problems. (Supersedes LC807.)
LC841. Glass and glass products—publications by members of the staff of the National Bureau of Standards, together with a list of Federal Specifications and Standard Samples. (Supersedes LC350.)
LC842. List of Commercial Standards. Revised January 1, 1947. (Supersedes LC836.)

Recent Articles by Members of the Bureau's Staff in Outside Publications [2]

Development of reference fuel scales for knock rating. Donald B. Brooks. SAE Journal (Transactions) (Society of Automotive Engineers, 29 West 39th Street, New York 18, N. Y.) **54,** No. 8, 394 (August 1946).
Effect of mildew on caselining materials. B. W. Scribner and E. Abrams. Paper Trade Journal (15 West 47th Street, New York 19, N. Y.) **123,** No. 15, 132 (October 10, 1946).
Experimental manufacture of paper for war maps. Charles G. Weber and Merle B. Shaw. The Paper Industry and Paper World (59 East Van Buren Street, Chicago 5, Ill.) **28,** No. 8, 1137 (November 1946).
Heat losses through floor slabs and testing of base board radiators. R. S. Dill. Official Bulletin, Heating, Piping and Air Conditioning Contractors National Association (1250 Avenue of the Americas, New York 20, N. Y.) **53,** No. 9, 21 (September 1946).
Integrating all textile research. William D. Appel. Proc. 17th Annual Meeting, Textile Research Institute (10 East 40th Street, New York 16, N. Y.), p. 30 (November 8, 1946).
Statistical inference applied to Naval engineering. J. H. Curtiss. J. Am. Soc. Naval Engineers (Navy Building, Constitution Avenue, Washington 25, D. C.) **58,** 335 (August 1946).
Testing large-capacity gas meters. A method that may be used in the field. Howard S. Bean, M. E. Benesh, Frank C. Witting. Gas (1709 West Eighth Street, Los Angeles 14. Cal.) **22,** No. 9, 33 (September 1946).

[1] Send orders for publications under this heading only to the Superintendent of Documents, Government Printing Office, Washington 25, D. C. Subscription to Technical News Bulletin, $1.00 a year; Journal of Research, $3.50 a year (to addresses in the United States and its possessions and to countries extending the franking privilege); other countries, $1.35 and $4.50, respectively. The price of other publications is indicated in the lists.

[2] These publications are not obtainable from the Government. Requests should be sent direct to the publishers.

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